THE STRATIGRAPHIC AND FAUNAL RELATIONSHIPS OF THE MEGANOS GROUP, MIDDLE EOCENE OF CALIFORNIA

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CONTENTS

INTRODUCTION

The problems connected with the divisions of the marine Tertiary of the West Coast are complicated and their solutions difficult. This is due to the original conditions of deposition and to the magnitude of the crustal movements which have affected all the formations of this province, including the Pleistocene. The sediments were, for the most part, deposited in geosynclinal troughs, some of which appear to have been rather local. The deposits are of enormous thicknesses as compared with those of the same period in the Gulf and Atlantic Coast provinces. The aggregate thickness of the Tertiary of the West Coast exceeds 40,000 feet. Clastic materials predominate, and, over wide areas, the beds are either unfossiliferous or the preservation of the fossils poor, due to the leaching out of the original material of the shells. The destructive leaching is more general in the marine Tertiary of California than in that of Oregon and Washington. Crustal movements occurred along the West Coast more or less interruptedly throughout the Tertiary, and the groups of strata representing the major epochs of this time are, as a rule, separated by angular unconformities. The intense folding and faulting which accompanied these movements, together with the paucity and poor preservation of the faunas, have made the problems of correlation difficult, and it is only by detailed mapping, combined with careful paleontological work, that we can hope ultimately to arrive at the final solution. Due in part to these conditions and also to the fact that workers have been few, little has been accomplished toward distinguishing minor faunal divisions in the Tertiary of the West Coast, i.e., such faunal divisions as

might be found in a group of beds belonging to one epoch of deposition.

The foregoing remarks have especial application in connection with the faunas of the marine Eocene of the West Coast, where the larger part of the work of differentiating them remains to be done. Until very recently, one of the largest and most important breaks in the Tertiary of California, an unconformity in the Eocene deposits, was entirely overlooked, and a considerable part of the marine Eocene section of the state, as well as of Oregon and Washington, has been described in a sequence the reverse of the fact.

The fauna of Dr. R. E. Dickerson's Siphonalia sutterensis zone, regarded by him as a part of the Ione formation in the foothills bordering the western front of the Sierra Nevadas, has been regarded until recently as coming from the uppermost Eocene of the West Coast. The beds of this horizon can be shown to belong well down in the Eocene section, and strata of the same age are found in the Coast ranges of California overlain unconformably by beds of Tejon age. The latter formerly were considered to be the older.

In a recent paper the writer has given a summary of his work[1] on the Eocene in the vicinity of Mount Diablo, and has presented evidence to show that there are at least three major stratigraphic and faunal divisions in the Eocene of this region. Previously, only two such divisions had been recognized. The beds of the new division, to which the name Meganos Group was applied, formerly were considered a part of the Tejon.

As will be brought out below, the writer is not the first to advocate a threefold division of the Eocene of the West Coast. The important fact to be remembered in this connection is that, while the fauna of the Meganos had been recognized by previous workers in this field as belonging to a distinct division of the Eocene, the Ione of Arnold and Hannibal and of Waring, the stratigraphic position of this horizon was wrongly determined and, instead of representing the uppermost Eocene of the West Coast, this division comes below the Tejon, and is the middle of the three Eocene divisions as now recognized.

[1] Bruce L. Clark, "Meganos Group, a Newly Recognized Division in the Eocene of California," *Bull. Geol. Soc. America*, Vol. XXIX (1918), pp. 281–96.

HISTORICAL SKETCH

The most detailed work on the Eocene of the West Coast, since the time of Gabb, is that of Dickerson.[1] He recognized only two stratigraphic units as belonging to this period, the Martinez (Lower Eocene) and the Tejon (Upper Eocene). As the result of his studies of the so-called Tejon, he outlined four faunal zones, thought to occupy four successive horizons in that group. These, beginning with the lowest, were the Turbinolia zone, the Rimella simplex zone, the Belanophyllia variabilis zone, and the Siphonalia sutterensis zone. The first three zones were described from the Eocene section in the vicinity of Mount Diablo, and the fourth from the Eocene bordering the foothills of the Sierra Nevadas, the beds of which apparently form part of the Ione formation.

In the paper in which Dickerson first outlined his ideas of the faunal succession of the Tejon we find the statement:[2]

> A study of the relationship between zone 3, Mount Diablo region, and the Siphonalia sutterensis zone and their geographic position suggest that the uppermost strata of the Marysville Buttes and Oroville were deposited by a transgressing sea, and that only in favored places along the western borders of the Sierra have the latest Eocene sediments been preserved from erosion. Lava caps such as that of the older Basalt of South Table Mountain have preserved these youngest Tejon sediments which have heretofore been regarded as Ione.

The first writers to suggest that there are more than two distinct stratigraphic units or groups in the Eocene of the West Coast were Dr. Ralph Arnold and Mr. Harold Hannibal in a joint review of one of Dr. Dickerson's papers. These writers, in their study of the Eocene of Washington and Oregon, recognized three horizons, the Chehalis (at the base), Oliqua, and Arago or Ione (at the top) formations, all higher than the Martinez (Lower Eocene). Their Chehalis horizon they referred to the

[1] R. E. Dickerson, "Note on the Faunal Zones of the Tejon Group," *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. VIII (1914), No. 2, pp. 17–25; "Stratigraphy and Fauna of the Tejon Eocene of California," *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. IX (1916), No. 17, pp. 262–534, Pls. 36–46.

[2] R. E. Dickerson, "Note on the Faunal Zones of the Tejon Group," *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. VIII (1914), No. 2, p. 24.

same period of deposition as the typical Tejon; they did not recognize their Oliqua in California; the Arago formation was correlated with the Ione along the Sierra Nevada front. Arnold and Hannibal agree with Dickerson in placing the marine beds of the Ione as uppermost Eocene in age, but disagree in that they considered this horizon to belong to a distinct epoch of deposition. The following statements are taken from the paper of Arnold and Hannibal[1]:

> The writers have shown that in Oregon and Washington the Eocene may be divided into three faunal divisions, the Chehalis, Oliqua, and Arago or Ione formations. The Chehalis formation is characterized especially by *Venericardia hornii* Gabb, *Meretrix californica* Gabb, and an austral flora, the Oliqua formation by *Pecten (Chlamys) landesi* or *Venericardia hornii* Gabb and a tropical flora, and the Arago or Ione formation by *Turritella merriami* Dickerson, a form of *V. hornii* with obsolete ribs (var. *aragonia* A. and H.), and a tropical flora.
>
> The Arago or Ione beds represent a horizon younger than any Tejon recognized in the Tejon or Puget Basin. The Arago or Ione beds occurring as they do in basins distinct from those in which the Tejon series is developed, and being formed at a different period, must be treated as a distinct division of the Eocene.

Professor C. E. Weaver in his study[2] of the Eocene sections of the Cowlitz River Valley, Washington, the section studied by Arnold and Hannibal and where they described their Chehalis horizon as being below the Oliqua, disagrees with them as to the sequence. His stratigraphic study of this section apparently shows that the beds of the Oliqua formation are below those of the Chehalis; in other words, Arnold and Hannibal had their section upside down, a condition similar to that which existed in California.

The first published announcement by the writer of his discovery that there are three distinct groups of strata in the Eocene section of Mount Diablo appeared in a paper to which reference has been made.[3] It was not until this paper was in page proof

[1] Ralph Arnold and Harold Hannibal, "Dickerson on the California Eocene," *Science*, new series, Vol. XXXIX (1914), No. 1016, p. 607.

[2] C. E. Weaver, "Eocene of the Lower Cowlitz River Valley of Washington," *Proc. Cal. Acad. Sci.*, 4th ser., Vol. VI (1916), Nos. 1, 2, and 3, pp. 1–17.

[3] Bruce L. Clark, "Meganos Group, a Newly Recognized Division in the Eocene of California," *Geol. Soc. Amer.*, Vol. XXIX (1918), pp. 281–96.

that sufficient evidence was obtained to show that the fauna of the Meganos belongs to the same epoch of deposition as the Eocene marine beds in the vicinity of Marysville Buttes and at Table Mountain near Oroville. These beds generally have been referred to the Ione formation, and considered to represent the uppermost Eocene of the West Coast. A statement to this effect was included in a note at the end of the paper and in the summary of conclusions.

Briefly summarized, the most important results brought out in the paper last mentioned are: that in the Eocene of the region of Mount Diablo there are at least three groups instead of two, as was formerly believed; and that the beds of this newly recognized epoch of deposition come between those of the Martinez (Lower Eocene) and those of the Tejon (Upper Eocene). It was found that the Meganos Group on the north side of Mount Diablo has a maximum thickness of nearly three thousand feet. These beds previous to this time had been generally mapped as Tejon. The unconformity between the Meganos and the Tejon in this area is such a marked one that it may be classed as one of the major breaks in the Tertiary of the Coast ranges. In places there is a difference of from 15° to 20° in strike, and a maximum difference of about 18° in dip between the beds of the Meganos and those of the Tejon above. It was also the conclusion of the writer that there is a marked difference between the fauna found in the beds below and that in the beds above this unconformity, and finally that the beds of the Meganos Group have a fairly wide distribution throughout the Coast ranges of California, in some localities having been mapped as of Martinez, and in others of Tejon, age.

PURPOSE OF PAPER

The purpose of this paper is to sum up the results of more recent studies of other Eocene sections in different parts of the Coast ranges, including the Mount Diablo section, which was described somewhat in detail in the first paper. The most important contribution is the evidence which shows that there are three general divisions in the Eocene of California, namely, the Martinez, Meganos, and Tejon, each of which may be considered as belonging to a distinct epoch. After discussing the various Eocene sections, reasons will be given for correlating the beds referred to the Meganos

Group in these different areas in the Coast ranges with one another and with the marine Ione formation in the Sierra Nevada foothills,

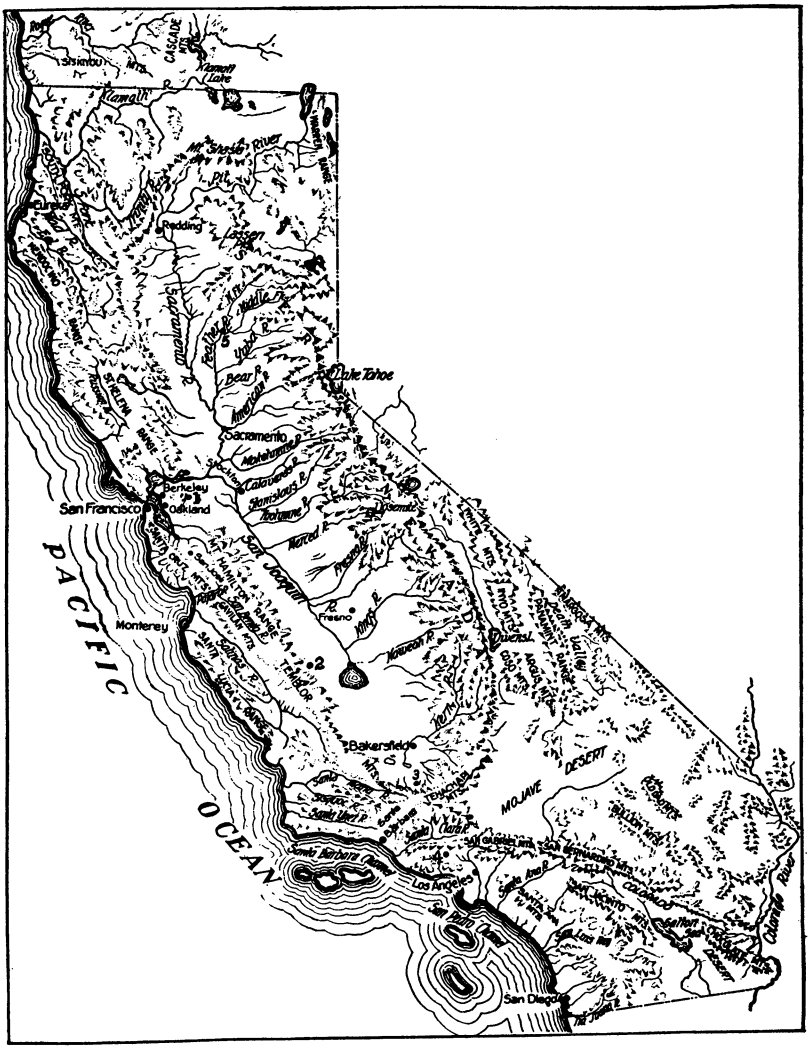


FIG. 1.—Outline map of California. The numbers indicate the locality of the different sections discussed in this paper: (1) Mount Diablo region; (2) region to the north of Coalinga; (3) south end of San Joaquin Valley; (4) Camulus quadrangle; (5) Table Mountain in the vicinity of Oroville.

as mapped and described by Lindgren and Turner, not, however, including the type section of the Ione.

THE MEGANOS GROUP IN THE VICINITY OF MOUNT DIABLO

Mount Diablo is a much faulted anticline of which the Franciscan series forms the core. The Shasta-Chico series (Lower and Upper Cretaceous) is represented in this section by more than ten thousand feet of shales and sandstone, on top of which, on either side of the anticline, are Eocene strata having a maximum thickness of nearly four thousand feet. These beds in turn are overlain by beds referable to the Oligocene, Miocene, and Pliocene. The two Eocene sections, the one on the north side of the Mount Diablo anticline and the other on the south side, will be considered separately as their outcrops are disconnected.

MEGANOS TO THE NORTH OF MOUNT DIABLO

The type section of the Meganos is on the north side of the Mount Diablo anticline. In this paper, the description of that section is largely a repetition of the data presented in the former paper, but adds some details.

The section extends from about one mile to the west of the old coal-mining town of Nortonville, east and a little to the south of the eastern edge of Mount Diablo Quadrangle. These beds, including the Martinez, Meganos, and Tejon groups, dip to the north, the angle of dip varying from 15° to 40°. The greatest width of the outcrops is about two and a half miles.

Stratigraphy and lithology.—The beds of the Meganos Group in this area rest unconformably on those of the Martinez Group. This unconformity, as stated above, was first described by Dickerson.[1] The lower Tejon, as recognized at that time, is the base of the Meganos, as described in this paper. The Meganos beds in this area have a maximum thickness of about three thousand feet. The section may be roughly divided into five lithologic members. Beginning at the base, these will be designated divisions A, B, C, D, and E.[2]

[1] R. E. Dickerson, "The Stratigraphic and Faunal Relations of the Martinez Formation to the Chico and Tejon North of Mount Diablo," *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. VI (1911), No. 8, pp. 174–76.

[2] The lower part of this section, that is, the Martinez and divisions A, B, and C of the Meganos, are best exposed in the section just to the west and south of the old town of Stewartville. The upper Meganos beds are best exposed on the ridge just to the north of Deer Valley and to the north of that ridge. The best Tejon section is to be found in the vicinity of the old town of Nortonville; also a very good section may be seen in the vicinity of the old town of West Hartley.

Summary of lithology of section.—The outline below is a generalized section of the Eocene groups as found on the north side of Mount Diablo. The Martinez portion of the section is copied from Dickerson's paper.[1]

The conglomerates at the base of the Meganos Group, division A, because of their peculiar character are worthy of mention. In the vicinity of Stewartville great angular slabs of fossiliferous Chico sandstone, some of them five, six, or more feet in length, are associated with well-rounded quartzitic and igneous bowlders. With them are numerous smaller limestone and sandstone pebbles, derived either from the Martinez or the Chico, showing that these beds are a true basal conglomerate. When followed to the east these conglomerates thin out rapidly.

The shales of division C of the Meganos Group are especially noticeable in that they are so different from anything found in the Tejon series on either the north or south side of Mount Diablo. The dark color, the calcareous lenses and nodules, the surface slaking into small fragments, the presence of carbonaceous material, and the layers of coarse sandstone which separate the different shale members all are similar to lithological characters of the

OUTLINE OF EOCENE GROUPS

		Feet
Tejon Group	6. Clay shales with minor amount of sandstone	500
	5. Fine, buff-colored sandstone; in places hard, calcareous layers contain marine fossils	175
	4. Sandy shales; exposures poor; soil very red	175
	3. Light gray to white, angular-grained sandstones, coarse to medium in texture; cross-bedding common, with minor layers of chocolate-colored shales; two important coal layers	75–400
	2. Chocolate-colored shales, ashy in places, with thin lenticular layers of coarse sandstone; coal layer locally known as Black Diamond vein	50
	1. Conglomerate	0–20
	Unconformity	

[1] R. E. Dickerson, "Fauna of the Martinez Eocene," *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. VIII (1914), No. 6, p. 71.

			Feet
Meganos Group	E	Clay shales and sandstones at top, grades down into fine, massive, poorly indurated sandstone; exposures of the beds of this division are very poor	0–1,500
	D	Sandstone of medium texture; thin-bedded near bottom; more massive at top; yellow brown to gray in color with about 100 feet of cross-bedded sandstone, eolian type. The massive sandstones near top contain lenses of harder calcareous and fossiliferous sandstones	0–300
	C	5. Dark slate-gray shales; bedding planes fairly distinct; light calcareous nodules and lenses	0–230
		4. Sandstone, fine to coarse in texture; in places forms a grit; contains thin clay lenses; in places contains considerable carbonaceous material	110
		3. Dark slate-gray shales, similar to (1) and (5)	90
		2. Sandstone, medium to fairly coarse; weathers on surface a rusty brown; grains chiefly of quartz and mica	50
		1. Dark slate-gray clay shale; bedding planes indistinct; carbonaceous material abundant	75
	B	Coarse to medium fine, quartzitic, gray to gray-brown micaceous sandstones, with some fine conglomeratic layers which are fossiliferous in the eastern part of the area. Sandstone quartzitic at one horizon	700
	A	Heavy conglomerates; changes to sandstone along the strike; bowlders composed of quartzites, chert, limestone, and large angular slabs of sandstone, containing typical Chico (Upper Cretaceous) fossils	0–50
		Unconformity	
Martinez Group		5. Gray-green shale	300
		4. Gray-green glauconitic sandstone; Trochocyathus zitteli beds	50
		3. Fine-grained gray sandstone	200
		2. Shales and sandstones	100
		1. Brown conglomeratic sandstone; Meretrix dalli beds	50
		Total?	
		Unconformity	
Chico			

Knoxville shales (Lower Cretaceous or Upper Jurassic), as seen in certain sections of this general area. These sediments probably are shallow-water deposits, perhaps laid down in estaurine or partially land-locked basins.

Divisions B and D of the foregoing sections contain much biotite. This may be best seen in the sandstones, division D forming the ridge on the north side of Deer Valley. In certain layers, biotite is very abundant, the flakes being fairly large. Grains of feldspar also are present. In fact, the beds may be described as arkosic. The basal sandstones, division B, are also micaceous. The fauna obtained from these arkosic sandstones indicates a subtropical temperature; the lithology, taken in connection with the evidence for warm subtropical waters, possibly points to arid conditions on the land.

In the basal chocolate-colored shales of the Tejon, many impressions of leaves, rushes, and fossil wood are found. These beds will undoubtedly yield a large and well-preserved flora. These leaf shales were apparently laid down in marginal marine swamps. The presence of shells of the genus Corbicula, in a layer of sandstone in the shales, testifies to brackish or fresh-water conditions.

The most important of the coal beds of this region, and one mined throughout most of the area, is found near the top of these lower Tejon shales. In the vicinity of Nortonville this bed is known as the "Black Diamond Vein." It is reported to have a maximum thickness of about four feet. Above this coal seam at Nortonville is a sandy, conglomeratic bed varying from 1 to 3 feet in thickness, which is highly impregnated with limonite. Rush and leaf impressions were found also in this layer. The close association of this bed with the leaf shales and coal, together with the fact that the limonite deposit is limited to a definite layer over a considerable area, suggests a primary rather than a secondary origin.

The coarse, cross-bedded, light-colored sandstones immediately above the shale may well have been deposited under somewhat similar conditions. Two of the important coal-layers, the "Little" and "Clark" veins, mined for many years at Nortonville and Somerville, are found in these sandstones. The coal of the Clark vein, which is about two and one-half to three feet in thickness,

as exposed in the mine at Nortonville, is intercalated between the coarse, white, quartzitic sands without a trace of shale.

Evidence for unconformity between Meganos and Tejon.—The most important evidence for unconformity between the Meganos and the Tejon is the great difference in strike between the beds of the two horizons, seen at numerous localities; this is very noticeable at the coal mine at Stewartville, where the difference approximates 15° (Fig. 1). The basal sandstone of division D is here in contact with the Tejon, the thickness of the sandstone being approximately 150 feet. Followed west of Stewartville, the sandstone disappears and the basal beds of the Tejon rest directly on the upper dark-colored shale (division C), and a little west and south of Nortonville the Tejon rests on the first sandstone member below the top of division C. Southeast of Stewartville the sandstone of division D emerges from beneath the Tejon and forms the ridge north of Deer Valley; the shaly sandstones and shales of division E also appear, and within 3 or 4 miles of Stewartville show their maximum thickness, 1,500 feet. In the canyon south of the Star Mine, not much more than a mile from Stewartville, the upper shales of division E are well developed.

Besides this difference in strike and the rapid emergence of the upper Meganos beds from beneath the Tejon, a marked difference in dip was noted at a number of localities southeast of Stewartville. In general it appears that there is a difference in dip between the two horizons throughout the entire length of the area. At the west end of the area southwest of Nortonville there is a maximum difference in dip of 18° between the upper Meganos beds and those of the lower Tejon. In the vicinity of Stewartville the difference approximates only about five degrees, while in the vicinity of West Hartley the difference is between 15° and 20°.

In the western part of the area under discussion, there are heavy conglomerates at the base of the Tejon which in some places have a thickness approximating 20 feet. Here they rest on the dark shale of division C, and at a number of localities a sharp irregular contact was seen, the bedding planes of the shale being cut off by the conglomerate. It is a noticeable fact, also, that there is considerable carbonaceous material at the contact. In

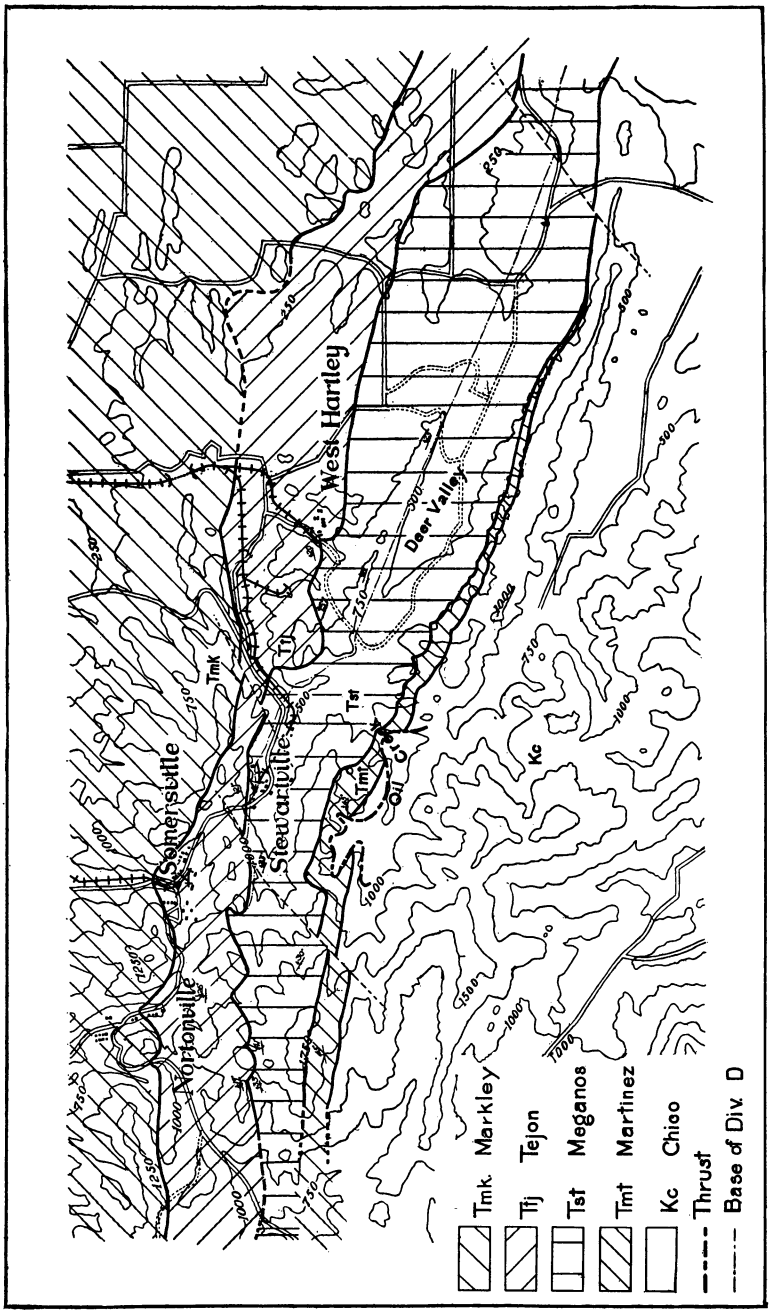


FIG. 2.—Areal map of the Eocene deposits to the north of Mount Diablo

the vicinity of Stewartville and West Hartley the conglomerates disappear and the chocolate shales at the base of the Tejon rest on the shales and shaly sandstones of division E of the Stewartville, making it impossible to find a sharp contact anywhere.

Fauna from Meganos beds.—The following is a preliminary list of the Meganos species obtained from the section described above. The majority of them came from the sandstone division D, a few species from the fine sandstones of division E, and a few from the basal sandstones near the eastern border of the Mount Diablo Quadrangle extending into the Byron Quadrangle to the east:

PELECYPODA

Acila gabbiana Dickerson
Antigona, 2 n. sp.
Arca hornii Gabb, n. var.
Avicula, sp.
Cardium brewerii Gabb, n. subsp.
Cardium marysbillensis Dickerson
Corbula diletata Waring
Corbula, n. sp.
Crassatellites, 2 n. sp.
Dosinia, n. sp.
Diplodonta cretacea Gabb
Glycimeris major Stanton, n. var.
Leda gabbi Conrad
Leda (cf. *alaeformis* Stanton)
Marcia (?) *conradi* Dickerson
Martesia, n. sp.
Macrocallista, n. sp. aff. M. Conradi Gabb
Modiolus ornatus Gabb
Ostrea, sp.
Psammobia, n. sp.
Periploma, n. sp.
Solemya, n. sp.
Solen, n. sp.
Solen, n. sp.
Spisula tejonensis Dickerson
Spisula (cf. *merriami* Dickerson)
Spisula, n. sp.
Tellina longa Gabb
Tellina, sp.
Tellina rêmondii Gabb
Tivela, n. sp.
Venericardia planicosta (cf. var. *merriami* Dickerson)

GASTROPODA

Acmaea, n. sp.
Actaeon, 3 n. sp.
Brachysphingus, 2 n. sp.
Calliostoma, n. sp.
Chrysodomus, 2 sp.
Calyptraea excentrica Gabb
Cancellaria Stantoni Dickerson
Cancellaria, n. sp.
Clavilithes, n. sp.
Conus, sp.
Cylichna, n. sp.
Cypraea, n. sp.
Exilia, sp.
Ficopsis, n. sp.
Fusinus, n. sp.
Galeodea sutterensis Dickerson
Haminea, n. sp.
Natica gesteri Dickerson
Natica hornii Gabb
Natica, n. sp.
Neptunea, n. sp.

Odostomia, n. sp.
Oliva, 2 n. sp.
Phos martini Dickerson
Siphonalia sutterensis Dickerson
Scaphander, n. sp.
Solarium, 2 n. sp.
Terebra, n. sp.
Turris, 5 n. sp.
Turris monolifera Cooper
Turritella, 2 n. sp.
Turritella merriami Dickerson
Whitneya, n. sp.

SCAPHODA

Dentalium (cf. *cooperi* Gabb)
Dentalium, n. sp.

CEPHALOPODA

A Nautiloid, genus indet.

ANTHOZOA

Turbinolia, 2 sp.
Flabellum, n. sp.
Stephanophyllia, n. sp.
Dendrophyllia (?), n. sp.

Comparison of Meganos and Tejon faunas.—Up to the present time 68 species have been reported from the Tejon beds on the north side of Mount Diablo. Most of these were listed either by Stanton or Dickerson in the papers already referred to. This upper fauna, referred by Dickerson to his Balanophyllia zone, contains a number of the species which are typical of the type section of the Tejon, such as *Meretrix hornii* Gabb, *Meretrix tejonensis* Dickerson, *Conus remondii* Gabb, *Ficopsis* cf. *cowlitzensis* Weaver, *Turritella uvasana* Conrad, *Turritella uvasana bicarnata* Dickerson.

The fauna of the Meganos as obtained from the type section described above is very different from that of the Tejon. Not more than five of the more than seventy determined species have been found in the Tejon as recognized in this section or known Tejon section. The presence of such described species as *Phos martini* Dickerson, *Siphonalia sutterensis* Dickerson, *Turritella merriami* Dickerson, *Schizaster diabloensis* Kew, together with a fairly large number of undescribed species, is the evidence for correlation of these beds with the Eocene of Marysville Buttes and Oroville, which contain the fauna of Dickerson's Siphonalia sutterensis zone, and with the beds referred to the Meganos on the south of Mount Diablo and the other Meganos sections described in this paper.

MEGANOS TO SOUTH AND SOUTHEAST OF MOUNT DIABLO

SECTION NEAR EAST EDGE OF CONCORD QUADRANGLE

When the first paper on the Meganos was published, comparatively little work had been done on the Eocene section south of the Mount Diablo anticline. A brief description was given in that paper of the beds exposed near the east border of the Concord Quadrangle which joins the Mount Diablo Quadrangle on the west. Here a typical Meganos fauna was found stratigraphically below beds containing a Tejon fauna.

Lithology.—In this section the Meganos beds have an approximate thickness of 2,000 feet. At the base there is between 150 and 200 feet of medium-fine yellow-brown sandstone beginning with about 20 feet of basal conglomerate which contains angular bowlders of fossiliferous Chico (Upper Cretaceous) sandstone, together with angular fragments of shale which is very similar to that found immediately below the contact. The upper 1,800 feet of the Meganos consists principally of dark-colored shales, fine shaly sandstone, and fine sandstone. Some of these shales are almost black and contain considerable lignitic material; they are identical in character with the dark-colored shales in the Meganos north of Mount Diablo.

There is a very marked lithological change between the Tejon beds of this section and those of the Meganos. The Tejon beds consist of 2,000 feet of massive, buff-colored quartzose sandstones which weather into cavernous bluffs on the north side of Pine Canyon a little farther east. At what appears to be the base of the Tejon is a narrow band of fine conglomerate made up of quartz and black and red chert, together with angular fragments of shale similar to the shale member immediately below.

Coal has been found at a number of localities in the basal beds of the Tejon, indicating the same general conditions as those recorded by the sediments on the north side of the mountain. In the sandstones near the base the species *Balanophyllia variabilis*, a coral which is common in the beds above the coal in the Tejon on the north side of Mount Diablo, was found in abundance.

This species is one of the most important markers of Dickerson's Balanophyllia variabilis zone.[1]

EOCENE SECTION SOUTHEAST OF MOUNT DIABLO

The Meganos and Tejon beds of the section just described can be followed continuously eastward, barring some cross-faulting, from the area on the Concord Sheet, to that in the Mount Diablo Quadrangle in which Dickerson made his study. In this section data were obtained for the establishment of three of his faunal zones.

The typical Tejon is represented throughout this area by heavy, massive, buff-colored quartzose sandstones, the outcrops of which form a prominent feature of the landscape. The Meganos beds of the more eastern area are composed for the most part of shale and shaly sandstone, with sandstones at the base, a section which is very similar to that just described, about ten miles to the west.

Detailed mapping has failed to show any marked difference in dip and strike between the Meganos and the Tejon in this southern area, such as occurs to the north of the mountain. At a few localities there is an apparent difference in dip between the beds of the two horizons; this, however, could not be verified with certainty, the division being recognized by a sharp change in lithology, and by faunal evidence.

Faunal zones.—The locality at which Dickerson did most of his work in the "Tejon" of Mount Diablo is southeast of the mountain, in the vicinity of Cave Point and Riggs Canyon. Dickerson divided his (so-called) Tejon into three horizons, the faunas of which were referred to as: (1) the Turbinolia zone; (2) the Rimella simplex zone; and (3) the Balanophyllia variabilis zone.[1]

[1] R. E. Dickerson, "Stratigraphy and Fauna of the Tejon Eocene of California," *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. IX (1916), No. 17, pp. 373–79.

[2] In the former paper referred to above, the writer stated that in this section thereis a marked difference in strike between the Meganos beds and those of the Tejon, and the difference was taken as one of the evidences of the unconformity between the beds of these two horizons. Later work, however, has shown that this apparent difference in strike is, in part at least, the result of faulting. Also it was stated that to the east of this area the Meganos disappeared due to this unconformity. At that time the writer had not recognized that the so-called Tejon beds to the east, as described by Dickerson, were in part Meganos.

Correlation.—Later work has shown that the faunas of the Turbinolia zone and the Rimella simplex zone belong to the Meganos epoch, while the fauna of the Balanophyllia zone represents typical Tejon.[1] A fairly large number of what are believed to be distinctive markers of the Meganos have been found in the beds referred to the lower two zones just mentioned. A few of the more important of these species which have been found in other Meganos localities and may be considered as markers of that horizon are: *Schizaster diabloensis* Kew, *Turbinolia pusillanima* Nomland, *Venericardia* cf. *merriami* Dickerson, *Trochocyathus imperialis* Nomland, *Ancilla (Oliverata) California* Cooper, *Rimella*, n. sp., *Siphonalia sutterensis* Dickerson, *Turritella merriami* Dickerson, *Turritella andersoni* Dickerson. In the beds representing the other zone, equally good evidence was obtained for correlating them with the typical Tejon.

It is interesting to note at this point that at the time Dickerson wrote his paper "Stratigraphy and Fauna of the Tejon Eocene of California," Arnold, Hannibal, and W. A. Waring correlated the Tejon in the vicinity of Mount Diablo with the Ione as recognized by them, which they recognized as an epoch distinct from and later than the Tejon. The faunas collected by Arnold and Hannibal, and by Waring from the Mount Diablo region appear to have come from the basal beds of the Eocene to the south and southeast of the mountain, Dickerson's lower Tejon recognized by the writer as Meganos. The locality from which the original so-called Ione marine fauna was obtained by these writers, with which they correlated the Mount Diablo fauna, was the south side of Table Mountain. This may be considered the type of Dickerson's Siphonalia sutterensis zone, the fauna of which he thought represented the highest horizon of the West Coast Eocene. This horizon is here placed well down in the Eocene, below the Tejon. Thus Arnold and Hannibal and Waring agree with the writer in their correlation of these lower beds in the Eocene section on the south side of Mount Diablo with the Eocene of Oroville, but they erred in regarding their Ione the uppermost Eocene of the Pacific Coast. They erred with Dickerson in their interpretation

[1] The species listed by Dickerson as Rimella simplex is a new species.

of the sequence, and if they had made sufficient collections, would undoubtedly have recognized the proper sequence.

EOCENE SECTIONS IN THE SOUTHERN PART OF CALIFORNIA IN WHICH THE MEGANOS GROUP IS REPRESENTED

In my first paper on the Meganos Group, reference was made to two Eocene sections in southern California, in which Meganos beds are present. One of these sections is north of Coalinga, on the west side of the San Joaquin Valley; and the other is in the vicinity of Simi Hills, Ventura County. During the summers of 1918 and 1919 several weeks were spent in studying these sections and also the Eocene at the south end of the San Joaquin Valley, where the type section of the Tejon is situated. The results of this work showed conclusively that beds of both Meganos and Tejon age are present in all of these areas, and that there is in each an unconformity separating the strata of these two series. The faunas from the Meganos of these three areas are very similar, containing in common a considerable number of highly ornamented species.[1]

THE SECTION NORTH OF COALINGA

Unconformity.—The unconformity between the Tejon and Meganos groups, in the Eocene section north of Coalinga, has been described by several writers,[2] most of whom considered the beds below the unconformity to be of Martinez age, while the beds above were considered to be Tejon. Dickerson[3] expressed the opinion that the Turritella andersoni beds, those here referred

[1] One of the most common species found in the Meganos of southern California is *Turritella andersoni;* in the past these beds have sometimes been referred to as the Turritella andersoni beds. This species is also found in the Meganos to the southeast of Mount Diablo.

[2] J. A. Taff, "Eocene of the Coalinga-Cantua District, Fresno County, California," *Proc. Pal. Soc. America* (1913), p. 127; E. T. Dumble, "Notes on Tertiary Deposits near Coalinga Oil Field and Their Stratigraphic Relations with the Upper Cretaceous," *Jour. Geol.*, Vol. XX (1912), pp. 28–37; Robert Anderson and Robert Pack, "Geology and Oil Resources of the West Border of the San Joaquin Valley, North of Coalinga, California," *U.S. Geol. Survey, Bull. 603* (1915), p. 66; R. E. Dickerson, "Stratigraphy and Fauna of the Tejon Eocene of California," *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. IX (1916), No. 17, pp. 382–87.

[3] R. E. Dickerson, *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. IX (1916), No. 17, pp. 382–87.

to the Meganos Group, were of Tejon age. My conclusion was stated as follows:[1]

> After studying the fauna from the Turritella andersoni beds, the same material on which Dickerson based his conclusions, the writer was impressed with the fact that there are so few typical Tejon species in this fauna. He does not agree with a number of the specific determinations that Dickerson made, as given in his list from locality 1817. Evidently Dickerson did not consider the possibility of there being a third group coming in between the Martinez and the Tejon, and that if this were so, one might well expect to find a larger number of species bridging the gap between this intermediate horizon and the Tejon than the gap between the Martinez and the Tejon.

Study of the Eocene series to the north of Coalinga showed conclusively that there is an unconformity in this section, and that the fauna obtained from above this contact is that of the typical Tejon, while the fauna below is referable to the Meganos. It is not the purpose in this paper to describe the lithology of the Eocene of this section except incidentally. Anderson and Pack of the United States Geological Survey have already described the lithology of this section[2] in detail. Accompanying their paper is a geologic map of the area. They referred the beds below the contact to the Martinez, and those above to the Tejon. The writer followed this contact nearly 20 miles, from a point near the old station of Oil City, to the Arroyo Honda near the west border of the Coalinga Quadrangle. Good evidence of an unconformable relationship was found along the entire distance.

As seen between the southern end of Domengine Creek and Cantua Creek (Coalinga Quadrangle), the upper beds of the Meganos consist of a white sandstone, which was mapped by Anderson and Pack as a part of the Tejon.[3] The contact between the Meganos and the Tejon comes in between this sandstone and somewhat similar sandstones of the Tejon. It is, as a rule, marked by a conglomerate, and is irregular at numerous

[1] Bruce L. Clark, "Meganos Group, a Newly Recognized Division of the Eocene of California," *Bull. Geol. Soc. Amer.*, Vol. XXIX (1918), No. 2, p. 294.

[2] Robert Anderson and Robert Pack, "Geology and Oil Resources of the West Border of the San Joaquin Valley, North of Coalinga, California," *U.S. Geol. Survey, Bull. 603* (1915), p. 66.

[3] Anderson and Pack, *op. cit.*, p. 66.

localities. The sandstones below the contact, due to the unconformity, thicken and thin very noticeably along the strike. Also, at a number of localities the lower sandstones show a dip and strike appreciably different from those of the Tejon beds above. While these differences amount at the most to only a few degrees, it is sufficient to cause the lower sandstone layers to be cut off obliquely, and on the cliff sections they are seen to abut against the basal beds of the Tejon (Figs. 3 and 4). Other evidence of this unconformity is the fact that numerous bowlders of sandstone, derived from the Meganos beds below, are found in the conglomerate at or near the base of the Tejon (Figs. 4 and 5).

Fauna.—An invertebrate fauna,[1] listed by Dickerson, was obtained from the beds above the unconformity just noted. It is, apparently, of typical Tejon age, containing a considerable number of highly ornamental molluscan species which have not been found in the Meganos.

The fauna obtained from the beds below the unconformity, the "Turritella andersoni beds," is essentially the same as that of the Meganos in the region of Mount Diablo, the ends in both places containing a fairly large number of highly ornamented species in common. The recognizable described species, which have been obtained from this portion of the section, are indicated in the list on page ooo.

Correlation.—Dickerson correlated the Turritella andersoni beds, just mentioned—the Martinez (?) as mapped by Anderson and Pack of the United States Geological Survey—with the lowest Eocene southeast of Mount Diablo (see p. ooo), the horizon of his Turbinolia zone. He believed that the beds of this horizon were older than the lowest beds in the type section of the Tejon. The writer agrees with both of these conclusions.

MEGANOS AT THE SOUTH END OF THE SAN JOAQUIN VALLEY

General statement.—An important problem which presented itself in connection with the differentiation of the Meganos from the Tejon, was whether any portion of the type section of the

[1] See list given under University of California locality 672. R. E. Dickerson, "Stratigraphy and Fauna of the Tejon Eocene of California," *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. IX (1916), No. 17, p. 430.

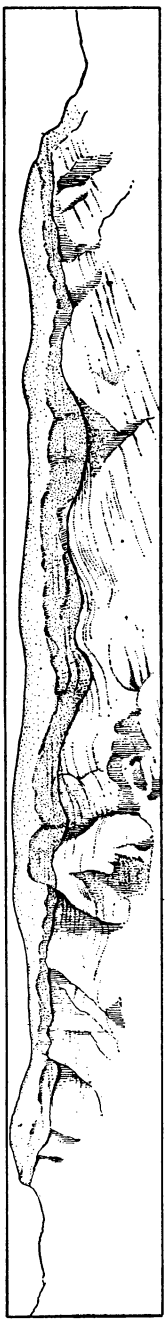


FIG. 3.—Diagrammatic sketch of panorama shown in Fig. 4, illustrating the unconformable contact between the Meganos and the Tejon. The beds, as shown in the view, are dipping into the hill at an angle of close to 30°.

Tejon might be referable to this newly recognized series and, if so, how much of the fauna, previously considered Tejon, belonged in reality to this other division.

The higher mountains immediately south of the San Joaquin Valley, the rocks of which are principally granites and older metamorphics, connect the Sierra Nevadas with the eastern Coast ranges. The hills immediately north of the granitic area and bordering the southern end of the valley are of Tertiary sediments, together with a minor amount of volcanic rock. The oldest unmetamorphosed sediments in this general section are of Eocene age, the outcrops of which may be traced in a narrow belt around the southern end of the valley for a distance of more than thirty miles. These Eocene beds rest on the granites and are overlain unconformably by beds of Oligocene or Lower Miocene age. The Tertiaries in this region have been folded and faulted and the beds as a rule dip at a high angle; in fact, in some localities the beds are overturned to the north, toward the valley, and the sequence is complicated by thrusting. This, however, is not true of the Eocene strata which border the granites. Here, along a narrow east-west belt for a distance of more than twenty miles, is found a normal section. The type section of the Tejon, in Grape Vine Canyon (the Spanish name is Canada de las Uvas) about thirty miles due south of Bakersfield, comes within this belt.

During the summer of 1919, ten days were spent in mapping and studying these Eocene rocks. While much more work remains to be

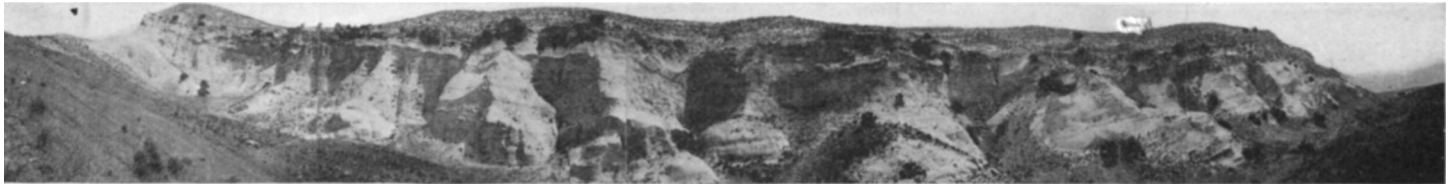
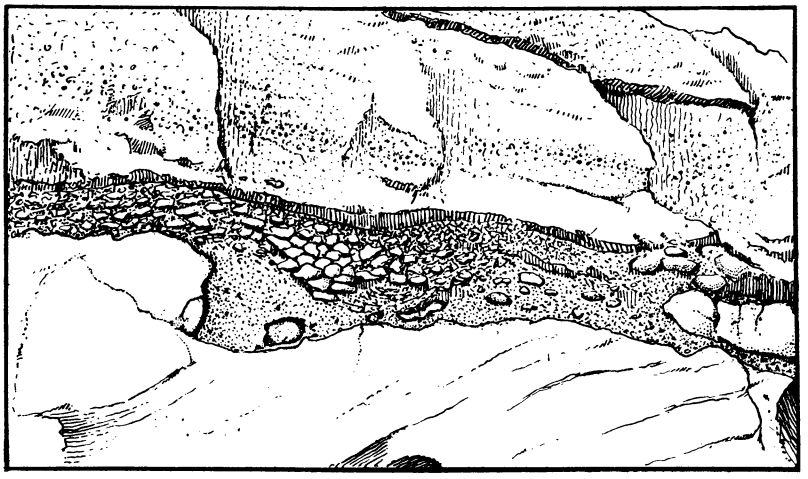


FIG. 4.—A panoramic view of cliff section composed of Meganos and Tejon rocks, as seen immediately south of divide between Cantua and Salt creeks Coalinga Quadrangle. The unconformable contact is near the top of the cliff a little below the line of vegetation. Photographed by Mr. Anthony Folger See diagrammatic sketch of this section in Fig. 3.

a



b

FIG. 5.—(*a*) A close view of the unconformable contact between the Meganos and the Tejon outcrops at a locality about one mile north of Cantua Creek, Coalinga Quadrangle. Photographed by Mr. Anthony Folger. (*b*) Diagrammatic sketch of contact shown in photograph above. The pebbles and bowlders in the conglomerate were derived from the sandstone immediately below.

done before this section is known in detail, enough data were obtained to show conclusively that both Meganos and Tejon are present. The portion of the Eocene outcrops studied extends from San Emigdeo Canyon east to Live Oak Canyon, the latter being the first canyon to the east of Grape Vine Canyon (see map on p. 151).

Faunal evidence for presence of Meganos.—Just to the east of San Emigdeo Canyon fossiliferous beds were found near the base of the section not far above the granite, and from these beds a good Meganos fauna was obtained.

The following is the list of species from this locality:

Cardium, n. sp.
Cardium cf. *marysvillensis* Dickerson
Glycimeris, sp. (?)
Leda fresnoensis Dickerson
Meretrix, n. sp.
Psammobia, n. sp.
Tellina, n. sp.
Venericardia, n. sp.
Amauropsis alveata Conrad
Calyptraea cf. *excentrica*
Natica hannibali Dickerson
Rimella, n. sp.
Turritella, n. sp.
Scaphander, n. sp.
Seraps erratica (Cooper)

This fauna contains several of the distinctive forms of the Meganos, such as *Leda fresnoensis* Dickerson, *Venericardia* n. sp., *Rimella* n. sp., *Natica hannibali* Dickerson, *Turritella* n. sp. Probably the most distinctive species in this fauna is the *Rimella* n. sp., which is very common in beds of the Meganos from Mount Diablo to southern California.

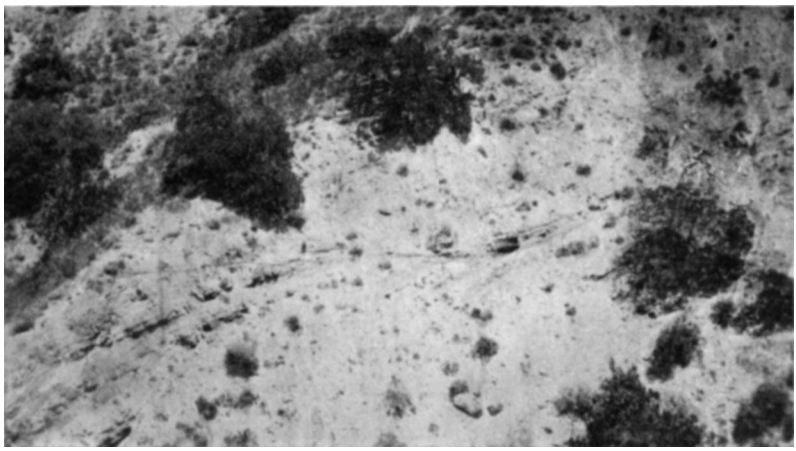
Unconformity.—These fossiliferous Meganos beds were found to rest unconformably below others containing a typical Tejon fauna, the latter connecting directly with the outcrops of the typical Tejon of Grape Vine Canyon.

One of the localities where the unconformable contact between the Meganos and the Tejon may be seen distinctly is about one-eighth of a mile back of the old Douglas ranch-house in the main canyon of San Emigdeo Creek.[1] Here the contact is beautifully exposed on the side of the canyon. There is a difference in dip between the two series of as much as 10° A basal conglomerate containing fossiliferous bowlders derived from the beds below was

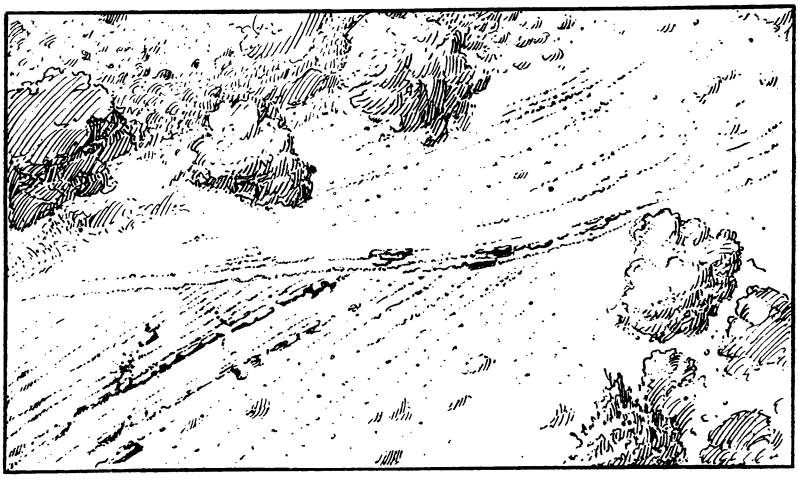
[1] Near south edge of NW. ¼, Sec. 5, T. 9 N., R. 21 W.

found along the contact (Fig. 6). The unconformity is also shown on the map (Fig. 7, p. 151).

At the locality just mentioned the Meganos beds have a thickness of less than 15 feet, and not more than 300 feet to the west



a



b

FIG. 6.—(*a*) A close view of the unconformable contact between the Meganos and Tejon outcrops as seen on the east side of San Emigdeo Canyon. (*b*) Diagrammatic sketch of contact shown in photograph above.

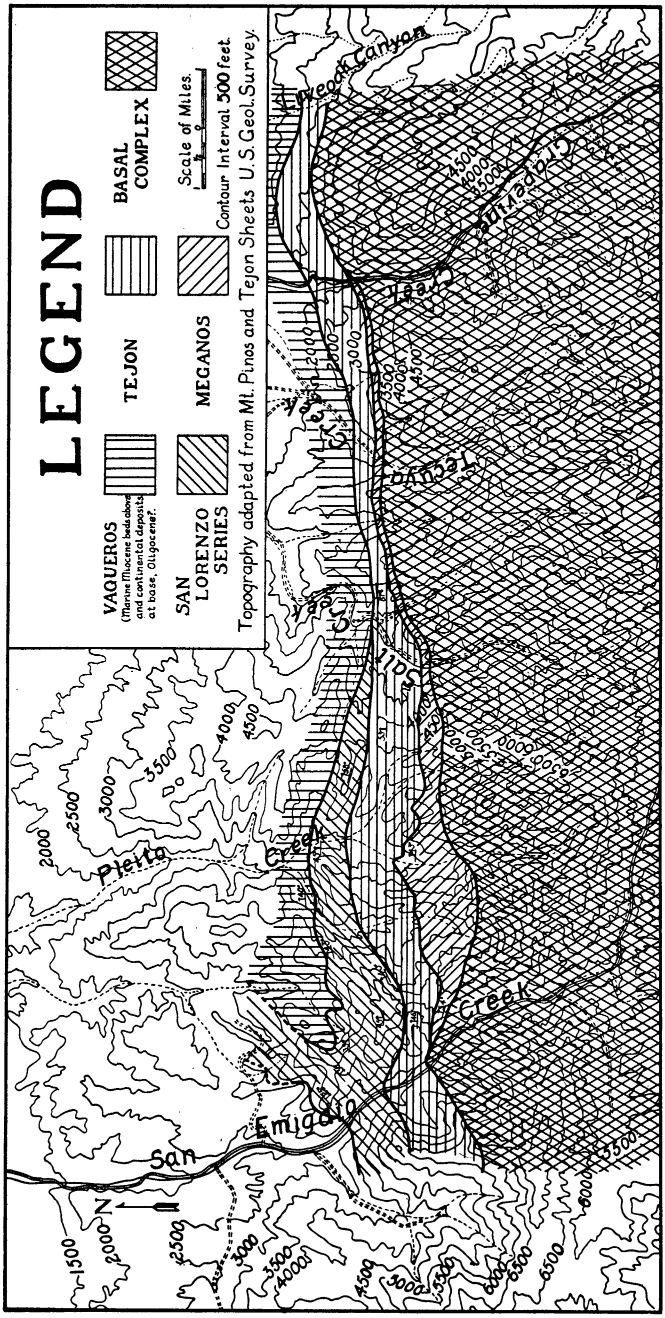


FIG. 7.—Areas map, showing distribution of Eocene and Oligocene outcrops at the south end of the San Joaquin Valley

the basal conglomerate of the Tejon rests on the granite. Just back of the ranch-house, a little farther west, a remnant of the basal Meganos sandstone outcrops below the basal conglomerate. Here the unconformity is evident. Traced east of this locality, the Meganos beds are found to thicken rapidly, reaching their maximum thickness near the head of Pleito Canyon about three miles to the east, where the Meganos beds have an estimated thickness of more than one thousand feet. As shown on the map, these beds thin out rapidly farther east, and in the canyon of Salt Creek, only a little more than four miles distant, their thickness probably is not more than one hundred feet. The conglomerate of the basal Tejon was traced to Tecuya Creek in the next large canyon east of Salt Creek. In Grape Vine Canyon the basal conglomerate of the Tejon was found to be separated from the granite by about twenty-five feet of unfossiliferous, coarse arkosic sandstone, together with a few feet of dark shales.

Thus the beveled Meganos is transgressed by the Tejon from west to east in the vicinity of Grape Vine Canyon, only a very small part of the Meganos being left, and in the next canyon to the east of Live Oak Canyon the Meganos beds fail to appear.

Lithology.—The Meganos outcrops are best exposed between Pleito and San Emigdeo canyons. The basal beds consist of several hundred feet of fairly indurated, coarse, reddish-gray arkosic sandstone. The upper part of the section is composed principally of sandy shales and platy shaly sandstone.

The Tejon beds of this region have a thickness of a little more than two thousand feet. The thickness in the vicinity of Grape Vine Canyon was estimated to be about twenty-four hundred feet. In the vicinity of this canyon the beds consist principally of medium-fine buff-colored sandstone, with lenticular harder, calcareous fossiliferous layers. This section, as already described by Anderson and Dickerson, is very uniform in lithology. To the west these beds become finer, and in the vicinity of San Emigdeo Canyon the larger part of the section might be described as a mudstone. In places lenses of conglomerate are found with the finer sediments, and at one horizon not very far from the base is a heavy layer of conglomerate that can be traced

for a considerable distance. It would appear that the Tejon beds in this last general locality may be delta deposits rather than typical marine deposits, such as those to the east in the vicinity of Grape Vine Canyon. This is borne out by the paucity of the fauna as well as by the lithology.

Fauna of the type Tejon.—The faunas obtained from different horizons in the type section of the Tejon, as found in Grape Vine Canyon, were studied by Dickerson. The invertebrate species were listed and a number of new species described by him.[1] Dickerson's conclusion, with which the writer agrees, was that the fauna obtained from the various horizons in the type Tejon, taken as a whole, is a unit. It has already been pointed out that Dickerson believed that these beds were somewhat younger than the Turritella andersoni beds at Coalinga or his lower Tejon from the south side of Mount Diablo, which beds of both localities are referred by the writer to the Meganos. In discussing this fauna, he says:[2]

> Beds about three hundred feet above the base (University of California locality 458) yielded an excellent fauna. This fauna, however, does not differ essentially from that of the beds higher in the section. The faunas from several other localities which are listed below do not differ materially from one another, but appear to represent one phase only. This faunal unity is in consonance with the sedimentary record as Anderson described it. . . . .
>
> The writer is in complete agreement with Anderson's view as expressed here in relation to the type Tejon. However, beds both higher and lower than the Eocene of Canada de las Uvas occur in other parts of the state, notably in the vicinity of Mount Diablo, along Cantua Creek, Coalinga Quadrangle, and at the Marysville Buttes.

As quoted in the paragraph above, Dickerson recognized that the fauna of the type Tejon was higher than that from the Lower Eocene beds on the south side of Mount Diablo, and higher than his so-called lower Tejon at Coalinga, the Turritella andersoni beds, which latter beds are here referred to the Meganos Group. He correlated the fauna of the type Tejon with that of his Rimella

[1] R. E. Dickerson, "Fauna of the Type Tejon; Its Relation to the Cowlitz Phase of the Tejon Group of Washington," *Proc. Cal. Acad. Sci.*, Vol. V (1915), No. 3, pp. 33–98.

[2] R. E. Dickerson, *op. cit.*, p. 40.

simplex zone. With this correlation I do not agree. As stated in the discussion on p. 000, the species *Rimella simplex* has not been found in the vicinity of Mount Diablo. The specimens from the south side of Mount Diablo, determined as such by Dickerson, belong to a new species which appears to be characteristic of the Meganos horizon. The so-called Rimella simplex beds of Mount Diablo come within the Meganos part of the section, and contain the typical species of that horizon.

EOCENE OF THE CAMULOS QUADRANGLE,[1] VENTURA COUNTY

General.—The fourth Eocene section studied during the summer of 1918 is that of the Camulos Quadrangle of Ventura County, California. The Eocene outcrops are found on both sides of the Simi Valley, the best and most complete section being in the hills on the south side of the valley, the strike of the beds almost paralleling the valley in an east-and-west direction. The late W. A. Waring described and mapped the geology of this area.[2] He recognized two Eocene divisions in this section, the Martinez and the Tejon, stating that apparently the Martinez (Lower Eocene) graded up into the Tejon. The fauna figured and described by him in his paper as Tejon is that of the Meganos. However, the Tejon also is represented in this section resting unconformably upon the Meganos.

Lithology.—This general area is being mapped and described by Dr. William S. W. Kew of the United States Geological Survey. According to him, the maximum thickness of the beds here referred to the Meganos is about three thousand five hundred feet. They consist principally of bluish-gray shales and shaly sandstones. Massive conglomerates are found near but not at the base. No sharp line of division between the Martinez and the Meganos has been found in this section. This, very possibly, is due to the lack of sufficient detailed work. The Tejon here consists of a series of about one thousand five hundred feet of coarse sand-

[1] The eastern half of Camulos Quadrangle comprises the Santa Susana and Calabasas quadrangles.

[2] W. A. Waring, "Stratigraphic and Faunal Relations of the Martinez to the Chico and Tejon of Southern California," *Proc. Cal. Acad. Sci.*, 4th ser., Vol. VII (1917), No. 4, pp. 41–124, Pls. 7–16.

stones, cross-bedded sandstones, and conglomerates. Above this is a great thickness of land-laid beds which are generally correlated with the Sespe formation.

Unconformity.—The contact between the Tejon and Meganos of this section is marked by conglomerates and conglomeratic sandstones. At a number of localities true basal conglomerate was found. The unconformity between the beds of these two horizons is also brought out by the mapping. On the south side of the Simi Valley near its east end the Meganos beds have a thickness of about one thousand five hundred feet; traced westward they thin out rapidly and near the west end of the valley disappear, due to overlap of the Tejon beds. This disappearance of the Meganos beds takes place in a very short distance, there being an appreciable difference in strike between the beds of the two horizons, which could only have been the result of crustal movements.

Fauna.—The following is a list of species obtained from the basal beds of the Tejon of this section, University of California locality 3311:

Cardium brewerii Gabb
Corbicula, n. sp.?
Glycimeris sagitata Gabb
Marcia? n. sp.
Tellina, sp.
Amauropsis alveata Conrad
Crepidula pilium (Gabb)
Ficopsis remondii Gabb
Natica hornii Gabb
Pseudoperissolax blakei (Conrad)
Turritella uvasana Conrad
Turris (*Surculites*) *sinuata* Gabb
Turris (*Surcula*) *io* Gabb
Whitneya ficus Gabb

Though this fauna is a small one, the writer feels confident in his correlation of these beds with those of the typical Tejon, because: (1) of the presence of an angular unconformity between the beds containing these species and those containing a typical Meganos fauna; (2) because it is believed that a number of the species listed above are characteristic of the Tejon. All are very common in the fauna obtained from the type section of the Tejon, and only four of the species have been found in beds of Meganos age: *Amauropsis alveata* Conrad, *Ficopsis remondii* Gabb, *Natica hornii* Gabb, and *Pseudoperissolax blakei* (Conrad).

The fauna obtained from the Meganos of this general section is one of the best preserved and largest from any known section

belonging to that epoch of deposition. A very large percentage of the species are common to the Meganos of the Coalinga section, as well as to that of the Mount Diablo region.[1]

Correlation.—It was from these Eocene beds in Ventura County that convincing evidence was first obtained that the Meganos belongs to the same horizon as that of the Eocene of Marysville Buttes and Table Mountain near Oroville, California, the beds of which localities contain the fauna of the Siphonalia sutterensis zone. The large number of highly ornamented species common to the Meganos of the Ventura County region and to the Eocene of these other localities seems to show conclusively that we are dealing with beds that are nearly, if not exactly, contemporaneous.

One of the localities, from which the writer has obtained the best-preserved Meganos fauna in the Ventura County area, is along Aliso Canyon about four miles northeast of the east end of Simi Valley. Here were found a number of the species which have been regarded as characteristic of the Siphonalia sutterensis zone.[2] The following quotation is taken from the published abstract of one of Dickerson's papers in which he refers to this section:

> A year ago Mr. Reginald Stoner discovered a locality in the Santa Susana Mountains, on Aliso Canyon of Devil Creek, just beneath the Miocene strata. The fossils from this locality represent a lower phase of the Siphonalia sutterensis zone and the fauna is essentially the same as the Siphonalia sutterensis zone of the Roseburg Quadrangle, on Little River near the confluence with the Umpqua.
>
> In the Simi Hills, a few miles away from the locality discovered by Mr. Stoner, the Rimella simplex zone of the middle Tejon stage occurs; the general absence of this zone through most of the Coast Range region is probably due to extensive erosion during the interval between upper Eocene and Oligocene time.

Dickerson, at the time the above-mentioned paper was written, supposed that these beds containing the fauna which he recognized

[1] For the list of the described species from the Meganos of the area under discussion the reader is referred to the list on pages 158–59.

[2] R. E. Dickerson, "Occurrence of the Siphonalia Sutterensis Zone, the Uppermost Tejon Horizon in the Outer Coast Ranges of California," *Bull. Geol. Soc. America*, Vol. XXIX (1917), p. 163.

as that of his Siphonalia sutterensis zone were at the top of the Eocene in this general section, and used this as corroborative evidence in support of his belief that this zone belongs to the uppermost Eocene horizon known on the West Coast. At that particular locality these beds are in unconformable contact with beds of Lower Miocene age. Further stratigraphic work by Kew, however, has shown that to the west other beds come in between these Eocene beds of Aliso Canyon and the Lower Miocene, and not more than four miles from that locality nearly 3,500 feet of other strata are found between. These include beds of true Tejon age, together with a considerable thickness of land-laid beds which have generally been called the Sespe formation. This is the section already referred to, in which there is a marked unconformity between the Meganos and the Tejon. Thus mapping and faunal work in this region show conclusively that the Eocene beds of Aliso Canyon, correctly considered by Dickerson as representing his Siphonalia sutterensis zone, lie unconformably below beds which contain a typical Tejon fauna.

FAUNA OF THE MEGANOS OF CALIFORNIA

The following is a list of the described species from the different Eocene localities in California which are now believed to be of Meganos age. The list is as complete as can be made at the present time. The writer takes entire responsibility of the specific determinations. The fauna, as listed here, represents only a comparatively small part of the known fauna, since a very large proportion of the known Meganos species has not yet been described. When this fauna is more thoroughly worked up, the evidence for the correlation of the different sections here described will appear more conclusive.

The general localities from which the species listed on pages 158–59 have been obtained are indicated in the columns on the side, as follows: M., Marysville; T.M., Table Mountain; Mt.D., Mount Diablo; Coal., Coalinga; Ca., Camulos and Calabasas Quadrangles; T.T., Type Tejon.

TABLE I

	M.	T.M.	Mt.D.	Coal.	Ca.	T.T.
Anthozoa:						
Flabellum (?) merriami Nomland				×		
Stephanophyllia californica Nomland	×		×			
Trochocyathus imperialis Nomland			×	×		
Trochocyathus perrini Dickerson	×		×	×		
Thamnasteria sinuata Nomland			×			
Turbinolia dickersoni Nomland			×	×		
Turbinolia pusillanima Nomland			×	×		
Echinodermata:						
Schizaster diabloensis Kew	×		×			
Pelecypoda:						
Acila gabbiana Dickerson	×	×	×	×		×?
Arca clarki Dickerson			×			
Arca hornii Gabb, n. var						
Cardium brewerii Gabb, n. subsp	×		×	×	×	
Cardium marysvillensis Dickerson	×	×	×	×	×	
Corbula diletata Waring						
Crassatellites lillisi Dickerson				×		
Cucullaea morani Waring					×	
Diplodonta cretacea (Gabb)						
Glycimeris fresnoensis Dickerson				×		
Glycimeris marysvillensis Dickerson	×					
Glycimeris major Stanton, n. var			×			
Isocardium tejonensis Waring	×		×	×	×	
Leda fresnoensis Dickerson				×		
Leda gabbi Conrad			×	×		×
Marcia (?) conradi Dickerson				×		
Modiolus ornatus Gabb	×	×	×	×	×	×
Nucula cooperi Dickerson	×					
Phacordes gyrata Gabb						
Spisula tejonensis Packard	×	×	×		×	
Spisula merriami?			×			
Tellina sutterensis Dickerson	×					
Tellina longa Gabb						
Tellina rémondii Gabb						
Tivela weaveri Dickerson					×	
Venericardia planicosta merriami Dickerson	×?	×?	×?			
Gastropoda:						
Acmaea ruckmani Dickerson		×				
Amauropsis alveata (Conrad)	×		×	×	×	×
Ancilla (Oliverata) californica Cooper	×	×	×		×	
Bittium featherensis Dickerson		×				
Bittium longissimum Dickerson	×					
Calliostoma arnoldi Dickerson	×					
Calyptrae excentrica (Gabb)	×	×	×	×	×	×
Cancellaria irelaniana (Cooper)	×	×				
Cancellaria stantoni Dickerson	×	×	×	×	×	×
Caricella stormsiana Dickerson	×					
Cerithiopsis orovillensis Dickerson		×				
Chrysodomus? martini (Dickerson) = *Phos martini* Dickerson	×	×	×			
Clavilithes tabulata Dickerson	×				×	
Cordiera gracillima Cooper	×	×				
Exilia perkinsiana Cooper	×		×			

TABLE I—*Continued*

	M.	T.M.	Mt.D.	Coal.	Ca.	T.T.
Gostropoda (*continued*):						
Ficopsis rêmondii Gabb, n. var.	×	×	×	×	×	×
Fusinus lineatus Dickerson	×					
Fusinus merriami Dickerson	×					
Galeodea sutterensis Dickerson	×	×	×		×	
Lyria andersoni Waring				×	×	
Metula harrisi Dickerson				×		
Mitra simplicissima Cooper	×				×	×
Molopophorus striatus Gabb			×			×
Monodonta wattsi Dickerson	×	×				
Murex nashi Dickerson	×					
Natica gesteri Dickerson			×	×		
Natica hornii Gabb						
Natica subobesa (Cooper)			×			
Natica hannibali Dickerson				×	×	
Natica nuciformis Gabb			×			×
Nyctilochus thunani Dickerson	×					
Olivella marysvillensis (Dickerson)	×					
Pseudoliva dilleri Dickerson					×	
Pseudoperissolax blakei (Conrad), n. subsp.	×		×	×	×	×
Seraphs erratica (Cooper)	×				×	
Siphonalia sutterensis Dickerson	×	×	×			
Solarium Weaveri (Dickerson)	×					
Solarium ulreyana Dickerson	×					
Spiroglyphus (?) tejonensis Arnold			×	×		
Strepsidura howardi Dickerson			×			
Terebra wattsiana Cooper	×					
Turris (Pleurotoma) cooperi Dickerson	×					
Turris (Pleurotoma) monolifera Cooper	×	×	×	×	×	
Turris (Pleurotoma) ulreyana Cooper	×	×				
Turris (Surcula) clarki Dickerson	×	×			×	
Turris (Surcula) crenatospira Cooper	×			×	×	
Turris (Surcula) davidsiana (Cooper)	×					
Turris (Surcula) holwayi Dickerson	×					
Turris fresnoensis Arnold				×		
Turris guibersoni Arnold				×		
Turris inconstans Cooper	×	×				
Turris suturalis (Cooper)	×					
Turritella andersoni Dickerson			×	×	×	
Turritella merriami Dickerson	×	×	×			
Voluta lawsoni Dickerson	×					

CORRELATION

CORRELATION OF MEGANOS SECTIONS IN COAST RANGES

The correlation of that portion of the different Eocene sections of the Coast ranges which has been referred to as the Meganos is based on both stratigraphic and faunal evidence. The stratigraphic evidence in itself, without the faunal, would

not be sufficient as it is impossible to trace the beds by mapping from any one of these general localities to another.

The stratigraphic evidence shows that in all the localities which have been examined, the Mount Diablo, Coalinga, and the Simi Hills regions, an unconformity exists between beds containing a typical Tejon fauna and others containing a fauna which is very different from that of the typical Upper Eocene, and also very different from that of the Martinez (Lower Eocene). As has been pointed out these general unconformities are not the result of local crustal movements, and surely cannot be classed as being "at most secondary order, i.e., such as might separate two formations within a group."[1] The beds below the upper unconformity are not Martinez in age, as shown by the fact that in the Mount Diablo region the Meganos beds rest unconformably on the Martinez. It is not possible at this time to present all the faunal evidence for correlating the different sections of the Meganos of the Coast ranges, as a large percentage of the species from this horizon are new and have not been described. The following discussion is based on described species only.

The best faunal evidence for correlating the Meganos of the Mount Diablo region with that of the Coalinga region is that presented by the corals. Three described species of corals are common to these two general sections; these are *Turbinolia pusillanima* Nomland, *Turbinolia dickersoni* Nomland, and *Trochocyathus imperialis* Nomland.[2] It has already been pointed out that Dickerson correlated the beds in the Coalinga region, which are here referred to the Meganos epoch of deposition, with those of his Turbinolia zone as recognized in the Eocene section

[1] R. E. Dickerson, "Stratigraphy and Fauna of the Tejon Eocene of California," *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. IX (1916), No. 17, p. 429.

[2] J. O. Nomland, "Corals from the Cretaceous and Tertiary of California and Oregon," *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. IX (1916), No. 5, pp. 59–76, Pls. 3–6.

Dr. Nomland listed *Turbinolia dickersoni* as being present in the Tejon of the Coalinga region; the type, however, came from the Meganos of this same section. Later examinations by Nomland of the specimens from the Tejon of this region, determined by him as *T. dickersoni*, show that this determination was a wrong one and that the form from this horizon is apparently a new species.—R. E. Dickerson, *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. IX (1916), No. 17, pp. 427–28.

southeast of Mount Diablo. This correlation apparently was based primarily on the corals. Dickerson believed that the beds of his Turbinolia zone represented a horizon lower than that of the type section of the Tejon. Thus, as regards the stratigraphic position of his Turbinolia zone with the true Tejon, he and the writer are in agreement. Besides the corals, there is a considerable number of highly ornamental molluscan species common to the Meganos of the Mount Diablo and Coalinga regions. A very large proportion of these are new species belonging to such genera as *Meretrix*, *Rimella*, *Turris*, *Ficopsis*, *Galeodea*, *Turritella*, etc. One of the described gastropod species, found in all three of the Meganos sections under discussion, is *Turritella andersoni*. This species appears to be a marker of the Meganos horizon.

The evidence for the correlation of the Meganos of the Coalinga region with that of the Camulos Quadrangle in Ventura County is even more conclusive. The faunas of the Meganos of these two localities have a very large proportion of their species in common, while in the more southern locality, Camulos Quadrangle, a number of species are found which are common to the Meganos of the Mount Diablo region, but which have not been found in the Coalinga region; among these are *Ancilla* (*Oliverata*) *californica* Cooper, *Galeodea sutterensis* Dickerson, and *Turritella merriami* Dickerson, none of which, as far as the writer is aware, have been found in the beds of typical Tejon.

CORRELATION OF THE MEGANOS WITH THE SIPHONALIA SUTTERENSIS ZONE OF THE IONE FORMATION

As already stated, it is my conclusion that the Meganos Group, originally described from the vicinity of Mount Diablo, belongs to the same general epoch of deposition as the beds of the Siphonalia sutterensis zone described by Dickerson[1] and which he considered the uppermost Eocene of the West Coast, and a part of the Ione formation described by Turner from the Jackson Quadrangle.

[1] R. E. Dickerson, "Note on the Faunal Zones of the Tejon Group," *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. VIII (1914), No. 2, pp. 17–25; "Stratigraphy and Fauna of the Tejon Eocene of California," *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. IX (1916), No. 17, pp. 363–524, Pls. 36–46.

What may be considered as the type section of the Siphonalia sutterensis zone is found at Table Mountain near Oroville, California. Dickerson[1] also referred the Eocene of the Marysville Buttes to this horizon, and later the fauna of the Umpqua formation of the Roseburg Quadrangle was included in the same horizon.[2] He recognized the distinctiveness of the Siphonalia sutterensis fauna from that of the type Tejon. The absence of many of the highly ornamented molluscan species, so common in the typical Tejon, and the presence of an equally large number of species in the former fauna not found in the latter, appear to be the principal reasons for his belief that the two faunas were not contemporaneous. Dickerson attempted to establish the stratigraphic sequence of his upper faunal zone in relation to that of the typical Tejon indirectly, not having the two faunas in the same section. His idea that the Siphonalia sutterensis fauna is younger than that of the typical Tejon appears to have been founded principally upon what he considered evidence for different stages of evolution of certain pelcypods, such as *Venericardia planicosta merriami* Dickerson and *Cardium marysvillensis* Dickerson. He believed that the variety *merriami* was derived from the variety *hornii*. Later stratigraphic work has shown that these species occur in a sequence the reverse of that which Dickerson originally supposed, the *Venericardia planicosta merriami* coming in beds older than those containing the variety *hornii*. The same is true of the other species, which were derived from typical Tejon species.

Another line of evidence which was presented as a basis for believing that the fauna of the Siphonalia sutterensis zone is closely related to that of the typical Tejon and therefore should be classed as Tejon, is the presence of a large percentage of species in the former fauna which, according to his determination, are also present in the typical Tejon. The writer has had access to all the collections which Dickerson had when he came to the foregoing conclusions. Their study has shown that there is a

[1] *Op. cit.*, pp. 403–6.

[2] R. E. Dickerson, "The Fauna of the Siphonalia Sutterensis Zone in the Roseburg Quadrangle, Oregon," *Proc. Cal. Acad. Sci.*, Vol. IV (1914), pp. 113–28, Pls. 11–12.

much smaller percentage of species common to the Siphonalia sutterensis zone and the typical Tejon than was supposed. As might be expected, there are a few species common to both faunas, but taken as a whole they are distinct. This will be still more evident when the entire fauna of the Meganos is described.

While the number of species common to the Eocene of the Marysville Buttes and Table Mountain, and to any one section of the Meganos of the Coast ranges mentioned in this paper (species not found in the typical Tejon), is not very large, yet they are forms such as would not be expected to have a very long range. A number of species from the Siphonalia sutterensis zone have been found in the Meganos of the Ventura County section, which have not been found in the Meganos of the Mount Diablo region, and vice versa. Taken as a whole, as indicated in the list, pages 158–59, there is a fairly large number of distinctive species common to the general Meganos of the Coast ranges and the beds of the Siphonalia sutterensis zone found in the Marysville Buttes and in the vicinity of Oroville. Among these are several corals together with a fairly large number of highly ornamented gastropoda and pelecypoda, the type species which are generally regarded as good horizon markers.

GENERAL CORRELATION

The consensus of opinion of those who are familiar with the Tejon fauna of California has been that it represents about the same stage of deposition as the Claiborne of the Gulf province, which in turn is correlated with the Lutetean subdivision of the Eocene of Europe. T. A. Conrad[1] as early as 1855 reported certain described Eocene species he had found in a bowlder obtained from near Fort Tejon, California, sent to him by W. P. Blake.

Later G. D. Harris in his paper entitled "Correlation of Tejon Deposits with Eocene Stages of Gulf Slope"[2] correlated the Tejon with the lower Claiborne on the basis of the identity of highly

[1] T. A. Conrad, "Paleontology," *Pac. R.R. Rept. App. to Preliminary Geol. Rept. of W. P. Blake* (1855), pp. 5–20.

[2] G. D. Harris, *Science*, Vol. XXII (Aug. 12, 1893), p. 97.

ornamented species common to the two, and also because of their generic assemblage.

Dickerson's[1] conclusion was the same as that of Harris. He listed a much larger number of identical or nearly identical species common to the Claiborne and the Tejon.

The nonconformity of the Meganos beds below the Tejon, together with the fact that the faunas of the two groups are very different, would seem to show that the former belong to a horizon lower than that of the lower Claiborne. That it does not represent the lowest Eocene is shown by the fact that the beds of the Martinez Group, which contains a fauna very distinct from that of the Meganos, lie stratigraphically and unconformably below those of the Meganos.

Dickerson's[2] conclusion after studying the fauna of the Martinez was that it is "in part the correlative of the Midway of the Gulf States and in part represents a division of time earlier than the Midway."

From our present knowledge of the Meganos fauna, its relationship appears to be closer to that of the Tejon than to that of the Martinez. If this be true, it would seem improbable that the Meganos is the equivalent of any part of the typical Midway stage. It more probably corresponds to the Wilcox. There is some direct evidence which appears to favor this assumption. This is the presence of species in the Meganos identical or nearly identical with certain well-known Middle Eocene species. For example *Turritella merriami* Dickerson with its numerous variations appears to be specifically close to *Turritella humerosa* Conrad, which is common in the Middle Eocene Wilcox of the Gulf province. One of the new species of turritella associated with *Turritella merriami* in the Mount Diablo region appears to be identical in at least one of its variations with the species listed by Harris[3] as *T. humerosa var.*

[1] R. E. Dickerson, "Stratigraphy and Fauna of the Tejon Eocene of California," *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. IX (1919), No. 17, p. 476.

[2] R. E. Dickerson, "Fauna of the Martinez Eocene of California," *Univ. Cal. Pub. Dept. Geol.*, Vol. VIII (1914), No. 6, p. 120–21.

[3] G. D. Harris, "The Midway Stage," *Bull. Amer. Paleontology*, No. 1, Pl. 11, Fig. 12 (1896).

A number of the undescribed species from the Meganos of different localities appear to be closely related to Wilcox species, if not identical with them. The correlation of the Meganos Group of California with the Wilcox of the east is only tentatively proposed. It is very possible that when the faunas of the Meganos and the Tejon are better known our ideas as to the relative position of the different Eocene horizons on the West Coast will be considerably revised.

SUMMARY OF CONCLUSIONS

The Meganos Group, the newly recognized division in the Eocene of California, has a wide distribution throughout the Coast ranges of the state. These beds represent an epoch of deposition distinct from both the Martinez below and the Tejon above. At the end of Martinez times there were orogenic movements which caused the sea to be withdrawn from what is now the Coast range province. When the sea again came, during the Meganos epoch, into this general region, its area was considerably different from that of the previous epoch. Following the deposition of the Meganos deposits, crustal movements again caused the withdrawal of the sea from the Coast range region. These movements were general throughout the Coast ranges, and over wide areas the Meganos beds were folded, the deposits of the next epoch of deposition, the Tejon, being laid across the upturned and eroded edges of these folded beds.

The Meganos of the Coast ranges belongs to the same epoch of deposition as the beds of the Siphonalia sutterensis zone, described and referred to as a part of the Ione formation by Dickerson. Previously the Siphonalia sutterensis beds had been considered to represent the uppermost Eocene of the West Coast.

A fairly large well-preserved fauna has been obtained from the Meganos horizon. This is very distinct from that of the Martinez (Lower Eocene). A few of the Meganos species are found in the Tejon. The fauna appears to be more closely related to the Tejon than to the Martinez, and is correlated provisionally with the Wilcox horizon of the Gulf and Atlantic Coast provinces.